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Optimizing insurers' investment portfolios: incorporating alternative investments*

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Abstract

The challenge posed by historically low-interest rates is particularly significant for insurance companies, especially those specializing in life insurance. This study investigates a potential solution by analyzing the impact of introducing low-correlation alternative investments into traditional investment portfolios. The research employs two methods: firstly, optimization using the Markowitz model, and the multicriteria optimization model is utilized to test the advantages of including alternative investments. Secondly, the study assesses the effects of interest rate fluctuations on both traditional and alternative investments through the Vector Autoregressive (VAR) model. The results from both optimization models during the analyzed period confirm the hypotheses, indicating that integrating alternative investments positively influences portfolio returns, risk management, and overall efficiency. Additionally, the study explores the influence of interest rate changes on domestic stocks, bonds, hedge funds, and managed futures. While there were theoretical expectations of a significant impact, confirming that interest rate changes have a stronger effect on bond and stock yields compared to hedge funds and futures yields remains inconclusive. Nevertheless, the research underscores the significance of diversifying investment portfolios with low-correlation alternative assets in the face of a low-interest rate period. These findings offer valuable insights for insurance companies seeking strategies to navigate the complexities of financial markets.

Keywords: *insurance companies, alternative investments, interest rates, investment portfolio, portfolio optimization*

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1. Introduction

Institutional investors in the European Union, particularly insurance and pension fund companies, are major investors in government bonds, with their value closely linked to interest rates. This connection presents a risk, partially managed through interest rate immunization. However, the decline in yields caused by low interest rates has created a structural challenge for insurance companies. They struggled to meet guarantees on life insurance policies through traditional investment returns, leading to the need for financing from alternative sources such as capital or borrowing. This emerging risk highlighted a pressing issue: how insurance companies handle this shortfall. This study explores a potential solution by investigating the incorporation of low-correlation alternative investments into portfolios, aiming to mitigate the challenges posed by the persistent low-interest-rate environment.

The term *Alternative investments* encompasses unconventional assets such as real estate, private equity, hedge funds, and commodities, expanding the investment landscape for investors. What sets alternative investments apart is their ability to expand investment possibilities and potentially enhance a portfolio's risk-return balance. This is because alternative investments typically have a low correlation with conventional investment forms. They are often less liquid, making their valuation complex, requiring investors to have longer investment horizons (Verbeek, 2010), thereby diversifying opportunities for investors (Anson, 2006). From the standpoint of institutional investors, the EU law governing management companies states that any collective investment undertaking not covered by the UCITS Directive[3] is deemed an alternative investment. This includes various investments such as hedge funds, risk and private capital funds, real estate-focused funds (e.g., REITs), commodity investments, infrastructure funds, and others (Basile, 2016).

Investments are a key component of an insurer's assets. They are regulated according to Solvency II regulatory framework where investment risk exposure is included in the calculation of capital requirements. In other words, according to current regulations, insurers can invest in any form of investment, but depending on its riskiness, they are obliged to reserve a certain amount of their own capital to cover potential losses or negative returns. Insurance companies are often conservative investors with a long investment horizon and invest a large part of their assets in government bonds which are perceived as a low-risk and non-volatile form of investment. For this reason, the largest share in the structure of investments is precisely such investments.

[3] Directive 2009/65/EC of the European Parliament and of the Council of 13 July 2009 on the coordination of laws, regulations and administrative provisions relating to undertakings for collective investment in transferable securities

It is important to point out that insurers today have the possibility to invest without limits in any form of investment (e.g. bonds, equity, real estate, other alternative investments etc.) if they have enough of their own capital to cover potential losses of such investment. The abolition of strict limits on permitted forms of investment has broadened the spectrum of selection of investments that insurers can include in their investment portfolio. Such an approach positively contributes to the development of financial markets, but on the other hand, it requires a greater level of focus and expertise in terms of risks that may arise from less common forms of investment.

During the analyzed period from 2006 to 2020, diversifying investment portfolios with alternative options could have alleviated the impact of low-interest rates on insurance companies' profits. Hedge funds and managed futures, unconventional investments, are now popular, especially among institutional investors (Schneeweis et al., 2011). Long-term correlations between the Credit Suisse Hedge Fund Index and standard stock and bond market indices, as depicted in Table 1, support this idea.

Table 1: Correlation Between Hedge Fund Returns and Traditional Investments (1994-2015)

Financial indices	Credit Suisse Hedge Fund Index	MSCI AC World GR (global stock market)	Barclays Global Aggregate TR (global bond market)
Credit Suisse Hedge Fund Index	1		
MSCI AC World GR	0.5677	1	
Barclays Global Aggregate TR	0.2776	-0.0059	1

Source: Authors as per Basile (2016)

The main research challenge lies in examining how incorporating alternative investments into institutional portfolios, particularly those of insurance companies, can counter the effects of prolonged low-interest rates. Another area of research involves finding the optimal balance between traditional and alternative investments. Insufficient research exists on how interest rate fluctuations affect both traditional (domestic stocks and bonds) and alternative investments, crucial for understanding the benefits of diversifying portfolios. Notably, there are limited local studies in this area. Investigating these fluctuations in Croatia's capital market gains importance, given the recent entry into the Eurozone, eliminating currency risks, and easing access to global financial markets.

Research on optimizing investment portfolios with alternative investments, such as hedge funds and managed futures, has shown significant advancements (Amin and Kat, 2003; Kat, 2005; Davó et al., 2013). Studies have highlighted the necessity of considering the non-normal distribution of returns in portfolio optimization (Keating and Shadwick, 2002; Bhaduri and Kaneshige, 2005; Anson et al., 2007; Abrams et al. 2012). Researchers have explored the impact of hedge funds and managed futures, emphasizing their positive effects on diversification, especially concerning higher moments of the return distribution like skewness and kurtosis. Incorporating alternative investments and using sophisticated techniques like multi-criteria optimization with higher moments can substantially enhance diversification (Kat, 2005; Abrams et al., 2012; Štimac, 2012; Flifel, 2014; Gautefall and Chen, 2017). For institutional investors, including insurance companies, these strategies hold the potential to improve risk-return profiles and create more resilient investment portfolios.

The study proposes two hypotheses. The first suggests that integrating alternative investments into a portfolio has a much more favorable effect on returns and risk compared to adding more traditional investments. Essentially, including alternative investments shifts the portfolio's efficient frontier upward. The second one states that fluctuations in interest rates impact traditional investments' returns more significantly than those of alternative investments. This aligns with the first hypothesis, emphasizing the benefits of alternative investments in low-interest-rate periods, which have been a persistent challenge for insurance companies.

The study is divided into six sections. The introductory part clarifies the research topic and the hypotheses. This is complemented by a review of existing research in the second section. The third section covers the applied research methodology. The fourth section presents the basis and results of the empirical analysis, detailing the variables used and their statistical characteristics. The fifth section explains the findings, their economic significance, and implications. The sixth section constitutes the conclusion, addressing the initial hypotheses and the paper's contribution, discussing limitations and challenges faced during the research, and providing directions for future research.

2. Literature review

Previous studies on optimizing investment portfolios by integrating alternative investments trace their origins back to papers like Lintner (1996), who first highlighted the low and occasional negative correlation between managed futures portfolios and portfolios comprising traditional investments in stocks and bonds. This finding enabled the creation of significantly more efficient portfolios. Kat (2005) examined the influence of adding hedge funds and managed futures as alternative investments to portfolios composed solely of stocks and bonds. Findings revealed that if managed futures constituted at least 50% of the alternative investments, there were no adverse effects on the portfolio.

Amin and Kat (2003) studied the impact of integrating hedge funds into stock portfolios and determined that due to their low correlation, hedge funds positively influenced portfolios when combined with stocks. This conclusion was supported by Otruba et al. (2006) and Hoevenaars et al. (2008). Bacmann et al. (2008) analyzed the correlation between various hedge fund types and traditional investments, refuting the notion that hedge funds lacked the necessary diversification properties.

A significant study by Jaggi et al. (2011) revealed the positive effects of hedge funds on the risk-return relationship of investment portfolios. In the context of the insurance industry, Davó et al. (2013) emphasized the diversification benefits of including life insurance-linked funds. Carayannopoulos and Perez (2015) studied catastrophe bonds and concluded that they were suitable for diversification, especially in crisis-free periods.

Researchers acknowledged that investment returns, especially from alternative options like hedge funds, did not follow a normal distribution. Consequently, they explored multi-criteria portfolio optimization considering higher moments, starting in the late 1990s. Davies et al. (2009) used polynomial goal programming to allocate capital to hedge funds and traditional investments, emphasizing the need to combine them for positive portfolio performance. Bergh and Rensburg (2008) also favored multi-criteria portfolio optimization over the traditional Markowitz model, considering the non-normal distribution of hedge fund returns.

Additionally, managed futures were considered as alternative investments. Abrams et al. (2012) examined the impact of including managed futures indices in investment portfolios with hedge fund indices, U.S. stocks, and global bond market indices. They highlighted the benefits of including managed futures for diversification, liquidity, transparency, and efficient use of free cash, especially for institutional investors like insurance companies. Kat (2005) explored the effect of including managed futures in investment portfolios, demonstrating their significant positive impact on diversification and higher moments of the return distribution.

In a Croatian case study, Štimac (2012) applied classic Markowitz optimization to portfolios primarily consisting of mandatory and voluntary pension fund return indices (MIREX and open funds A, B, and C) and cash. These investments were combined with alternative forms such as real estate, commodities, private equity, and hedge funds from 2002 to 2010. The study confirmed that including alternative investments in MIREX led to higher returns and lower risks. However, this study did not employ multi-criteria optimization or consider higher moments of the return distribution such as skewness and kurtosis.

By building upon the foundations laid by past studies, this research endeavors to provide nuanced insights. The study aims to explore not only the diversification benefits of alternative investments but also their potential to counter the challenges posed by prolonged periods of low-interest rates. Through empirical analysis and a multi-criteria approach, this research aims to offer valuable insights, guiding institutional investors in making informed decisions when constructing resilient and balanced portfolios.

In the context of the influence of macroeconomic variables on the returns of forms of investment, a scarce number of domestic scientific papers dealing with this issue was recorded, especially when it comes to alternative forms of investment. Jakšić (2008) performed an analysis of the influence of the monetary aggregate M4 and interest rates on CROBEX was carried out using Johansen's co-integration approach. In the paper, it was determined that there is a connection between the variables in the long term. Variables representing interest rates were interest rates on long-term loans to companies in Kuna (HRK) with a currency clause. The analysis period was 02/2000-05/2007 with a monthly data frequency.

Anđelinović (2011) analyzed the impact of macroeconomic variables (industrial production, monetary aggregate M1, inflation) on returns and riskiness of asset classes (Croatian stocks and bonds, EU bonds, Croatian money) using the VAR methodology. The results of the VAR analysis in most cases do not show Granger causality, i.e. it has not been proven that the movement of selected macroeconomic variables and economic cycles precedes the movement of yield and riskiness of selected asset classes. The analysis period is 2000-2010 with a monthly data frequency.

Benigno (2016) investigated the relationship between changes in 10-year government bond yields and stock returns in 14 developed countries over the period 1999-2015. Empirical results indicated a significant heterogeneity of the observed countries regarding the relationship between interest rates and the stock market.

Lütkepohl and Netšunajev (2018) use a cointegrated structural vector autoregressive model to investigate the relationship between monetary policy in the euro area and stock markets. The model results indicate that contractionary monetary policy shocks lead to long-term declines in stock prices. The analysis period is 01/1999-12/2014 with a monthly data frequency.

Jareño et al. (2019) investigate the impact of a change in the level, slope and roundness of the interest rate curve on US stock sector indices using an asymmetric nonlinear cointegration approach.

3. Methodology

Given that the research focuses on investment portfolios, the initial step involves defining them. An investment portfolio, as a variable, comprises the allocations of selected investment forms calculated using a relevant optimization method, representing the solution of the applied model. A traditional investment portfolio includes exclusively traditional investment forms, while the portfolio's return is defined as the first central moment of the return distribution. The portfolio's return is measured as the weighted sum of the allocations obtained for alternative and traditional investment forms through the conducted optimization. On the other hand, the portfolio's risk is defined as the variance/standard deviation of the investment portfolio, representing the second central moment of the return distribution.

Portfolio efficiency is defined as a relevant measure of portfolio performance based on the tested hypothesis. In the Markowitz optimization model, the Sharpe and Sortino ratios are used because the model assumes normality, eliminating the need to include higher moments in the model and measures. The Sharpe ratio is obtained by the following expression:

$$SR_i = \frac{E(r_i) - E(r_f)}{\sigma_i} \tag{3.1.}$$

where SR_i represents the Sharpe ratio of the investment class, $E(r_i)$ the expected return of the investment class i, $E(r_f)$ the expected return on a risk-free asset (e.g. treasury bill), and the risk of σ_i investment class measured by the standard deviation. The Sortino ratio is obtained using the same expression as the Sharpe ratio, except that the standard deviation of below-average returns is taken in the denominator.

Consequently, evaluating efficiency only requires these ratios, as their values depend solely on the first two moments of the return distribution. Conversely, in the multi-criteria optimization model, the Omega measure is used since it is a pertinent measure of portfolio efficiency when the distribution does not follow a normal shape (Šego et al., 2018). The omega ratio was developed by Keating and Shadwick (2002) to overcome the inadequacy of many traditional efficiency measures applied to forms of investment classes whose return distributions deviate from the assumption of normality. Omega measure is obtained by the following expression:

$$\Omega(r) := \frac{\int_r^b [1 - F(x)]dx}{\int_a^r F(x)dx} \tag{3.2.}$$

where $F(x)$ represents the cumulative distribution of the yield function, bounded by endpoints a i b, together with a defined threshold r (Keating and Shadwick, 2002).

The first hypothesis will be tested by optimizing the portfolio using both the Markowitz and multi-criteria models, incorporating the mentioned variables. The results of the optimization process will determine the outcome of the test. All calculations and optimizations were conducted using the R programming language. Monthly returns were computed based on the provided data, along with variance, skewness, and kurtosis data for each index or asset form.

When optimizing with N investment forms, calculating N expected returns, N+1 variances and covariances, N+2 coefficients for skewness and co-skewness, and N+3 coefficients for kurtosis and co-kurtosis is necessary. As the number of variables increases, the complexity grows exponentially. However, symmetry reduces the calculation to *only* N+2 coefficients for skewness and co-skewness, and N+3 coefficients for kurtosis and co-kurtosis (Škrinjarić, 2013). Using a multifactor model can help manage the exponential increase in parameters when more variables are included (Boudt et al., 2015). The general co-skewness coefficients are determined through the formula:

$$s_{ijk} = E\left[(R_i - E(R_i))(R_j - E(R_j))(R_k - E(R_k))\right] \quad (3.3.)$$

while the coefficients for co-kurtosis are calculated using the formula:

$$k_{ijkl} = E\left[(R_i - E(R_i))(R_j - E(R_j))(R_k - E(R_k))(R_1 - E(R_1))\right] \quad (3.4.)$$

Estimating coefficients in small samples can be highly variable. Shrinkage estimators offer a solution, as proposed by Boudt et al. (2017) for analyzing hedge fund portfolios. These estimators consider expected returns, variance, and skewness, enhancing accuracy. Ledoit and Wolf (2003) employ a similar method for stock return covariance estimation, while Martellini and Ziemann (2010) stress the significance of advanced estimators for co-skewness and co-kurtosis parameters, particularly in multi-moment portfolio analysis.

The second hypothesis will be examined using the VAR methodology, focusing on the Vector Autoregressive (VAR) model. This test aims to enhance understanding of how changes in interest rates affect the returns of chosen traditional and alternative investments. It seeks to validate if the assumed impact of variables in the model aligns with economic theory, particularly the relationship between interest rates and traditional investments like bonds. Economic theory suggests a specific connection between macroeconomic variables and financial markets, such as the influence of interest rate fluctuations on stock and bond returns. The official Eurostat tool (JDemetra+) was employed to check for seasonal components in time series variables as a preliminary step. The VAR model can be defined as per Guidolin and Pedio (2018):

$$y_t = \boldsymbol{a}_0 + A_1 y_{t-1} + A_2 y_{t-2} + \ldots + A_p y_{t-p} + \varepsilon_t = \boldsymbol{a}_0 + \Sigma_{i=1}^{p} A_i y_{t-1} + \varepsilon_t, \quad (3.5.)$$

where $y_t = [y_1t\ y_2t\ \dots\ y_Nt]$' is a N-dimensional vector containing N endogenous stationary variables, $a_0 = [a_{10}\ a_{20}\ \dots\ a_{N0}]$' is a N-dimensional vector of constants, A_1, A_2, … , A_p are N×N matrices of autoregressive coefficients, and $\varepsilon_t = [\varepsilon_1 t\ \varepsilon_2 t\ \dots\ \varepsilon_N t]$' is the vector of random processes.

The initial step in every VAR analysis involves testing the stationarity of variables, requiring unit root tests. Stationarity testing employs the Phillips Perron and Augmented Dickey Fuller (ADF) tests. Both tests are robust; ADF corrects autocorrelation through lags, while the Phillips-Perron test applies non-parametric corrections to the test statistic. VAR model estimation was performed using R studio. Relevant functions were utilized to link time series of observed variables, and the lag order (p) was determined using the *VARselect* function, which automatically generated the optimal lag order based on the following information criteria: Akaike Information Criterion (AIC), Schwarz Criterion (SC), Hannan-Quinn Criterion (HQIC), and Final Prediction Error (FPE).

After model estimation, innovation analysis commenced with the Granger causality test for each individual variable in the model concerning others. Granger causality determines the order of variables in impulse response function and variance decomposition. Causality, in the Granger sense, does not necessarily mean one variable causes another; instead, it signifies that including prior values of variable A contributes to a better description of the dynamics of variable B. The innovation analysis further utilized impulse response functions to discern the impact of shocks on specific variables within the model. Additionally, variance decomposition was performed, assessing the proportion of forecast errors explained by shocks in all variables. The variance of each variable could be dissected into components caused by shocks in the variable itself and portions resulting from shocks in other variables.

4. Empirical data and analysis

This section examines the impact of including alternative investments on the portfolio and how it responds to changes in interest rates. It begins by outlining the statistical insights of chosen variables before transitioning into model estimation.

4.1. Variables and descriptive statistics

Main variables for hypothesis testing include alternative and traditional investment forms, with monthly returns spanning from 2006 to 2020, totaling 180 observations. When comparing investment returns, annualization is done by compounding daily or monthly returns into yearly figures, based on trading days (252) or months (12) (Romero and Balch, 2015).

The variable *Alternative forms of investment* signifies the proportion of alternative investments (hedge funds and managed futures) in the portfolio, represented by financial indices. *Hedge fund returns'* data is sourced from the Barclay Hedge Fund Index, while *managed futures* data come from the Barclay BTOP50 index. Both indices lack exchange-traded funds (ETFs) tracking their movements. The variable *Traditional forms of investment* represents the proportion of traditional investments, including domestic and foreign government bonds, stocks, corporate bonds, and cash equivalents. Monthly returns for domestic and foreign stocks and bonds are based on corresponding indices. Data is obtained from Zagreb Stock Exchange and Bloomberg.

Due to data availability limitations, adjustments were made to *domestic stock* and *bond* series, supplementing earlier periods with monthly returns of the CROBEX and CROBIS base indices. Monthly returns for *US stock market* movements are represented by changes in the S&P 500 Index from 2006 to 2020. Similarly, monthly changes in returns for *European stock markets* are captured by the MSCI Europe Index during the same period. For *global stock market* movements, data are derived from the S&P Global 1200 Index, and for emerging markets, the MSCI Emerging Markets Index is used, both covering the period from 2006 to 2020. All data regarding foreign stocks are sourced from Bloomberg and are in the form of exchange-traded funds reflecting overall market performance.

Regarding *foreign government bonds in the EU market*, monthly changes in returns are tracked using the FTSE EMU Government Bond Index (EGBI) from 2006 to 2020. *Corporate bond performance in the EU market* is assessed through the Barclays Euro Corporate Bond Index during the same period. For *US government bonds*, the Barclays U.S Aggregate Bond Index is used, and for global bonds, the Barclays Global Aggregate Bond Index is employed. Data for *bonds in developing markets* are represented by the J.P. Morgan Euro EMBI Global Diversified Index, all sourced from Bloomberg. These indices, reflecting the overall bond market performance, are structured as exchange-traded funds traded on the stock exchange.

Cash equivalents' returns data are from the ZB Plus fund, a short-term bond fund, reflecting changes in Croatian money market funds due to regulatory shifts by the Croatian Financial Services Supervisory Agency (HANFA). These adjustments account for investments in short-term, highly liquid instruments like short-term bonds, cash, deposits, and treasury bills.

Table 2 presents the statistical summary of monthly returns for chosen domestic and foreign traditional as well as alternative investment options spanning from January 2006 to December 2020, comprising a total of 180 data points.

Table 2: Descriptive statistics for chosen investment alternatives

Type of investment	Index	Expected return	Std. dev.	Skewness coefficient	Kurtosis coefficient	Jarque-Bera	*p*-value
Croatian Government Bonds	CROBIStr	0.0025	0.012	-0.137	3.299	82.18	0.00
Croatian Stocks	CROBEXtr	0.0003	0.067	-0.925	7.157	409.79	0.00
Cash	ZB Plus[4]	0.0018	0.002	1.739	3.906	205.14	0.00
EU Bonds	FTSE EMU	0.0034	0.012	-0.030	0.333	0.86	0.65
EU Stocks	MSCI Europe	0.0013	0.056	-0.781	2.036	49.39	0.00
Hedge funds	Barclay Hedge Fund	0.0044	0.020	-1.221	4.728	212.36	0.00
Futures	BTOP50	0.0020	0.019	0.137	-0.174	0.79	0.67
US Bonds	Barclays U.S Aggregate	0.0037	0.009	0.109	1.072	8.97	0.01
US Stocks	S&P 500	0.0061	0.044	-0.889	2.247	61.59	0.00
Global Bonds	Barclays Global Aggregate	0.0033	0.015	-0.239	1.010	9.37	0.01
Global Stocks	S&P Global 1200	0.0042	0.047	-0.961	2.662	80.82	0.00
EM Bonds	J.P. Morgan Euro EMBI	0.0042	0.114	-0.291	86.175	55698.77	0.00
EM Stocks	MSCI EM	0.0033	0.064	-0.934	3.541	120.23	0.00
EU Corporate Bonds	Barclays Euro Corporate	0.0030	0.012	-1.564	9.587	762.70	0.00

Source: Authors' calculations

Table 3 presents a correlation coefficient matrix illustrating the relationships among the observed investment forms.

[4] Refers to the funds itself.

Table 3: Correlation matrix

	#	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Croatian Government Bonds	1	1													
Croatian Stocks	2	0.37	1												
Cash	3	-0.14	-0.03	1											
EU Bonds	4	0.20	-0.16	0.10	1										
EU Stocks	5	0.30	0.60	0.02	-0.07	1									
Hedge funds	6	0.32	0.66	0.06	-0.10	0.88	1								
Futures	7	-0.01	-0.03	0.03	0.28	0.07	0.12	1							
US Bonds	8	0.16	0.00	0.17	0.60	0.09	0.05	0.20	1						
US Stocks	9	0.30	0.59	-0.04	-0.07	0.88	0.87	0.04	0.03	1					
Global Bonds	10	0.22	0.20	0.17	0.38	0.45	0.32	0.20	0.72	0.30	1				
Global Stocks	11	0.31	0.63	-0.01	-0.08	0.96	0.92	0.06	0.07	0.97	0.39	1			
EM Bonds	12	-0.01	0.07	0.03	0.14	0.11	0.10	0.10	0.11	0.12	0.08	0.11	1		
EM Stocks	13	0.29	0.59	0.11	-0.07	0.86	0.88	0.06	0.16	0.78	0.48	0.87	0.13	1	
EU Corporate Bonds	14	0.36	0.31	0.16	0.56	0.46	0.55	0.13	0.49	0.46	0.46	0.49	0.11	0.47	1

Source: Authors' calculations

4.2. Portfolio optimization using Markowitz and Multi-criteria models

The Markowitz optimization process starts with traditional investments, including Croatian bonds, stocks, and the money market. Additional foreign traditional investments and alternative variables are gradually added. Constraints ensure realistic allocations, with Croatian bonds making up 40-50% of the portfolio. The optimization minimizes risk based on insurance companies' preferences, employing 10% increments for practical application.

Another reason for conducting optimization with constraints lies in the current insurance regulatory framework, such as Solvency 2, governing investments. Although formal limits for investing assets no longer exist, the new regulation mandates capital requirements contingent upon the riskiness of the assets. In essence, insurers are required to reserve more capital for high-risk assets and less for those considered lower risk. Hence, when conducting optimization, weight constraints were established to ensure that portfolios include a higher proportion of domestic bonds. These bonds are identified as investments with the lowest risk according to Solvency 2 guidelines. Moreover, they hold the most significant share in insurers' investment portfolios.

Table 4 presents results of portfolio optimization for the first ten portfolios.

Table 4: Optimization results (portfolios 1-10)

Type of investment/ # of portfolios	Shares in the portfolio									
	1	2	3	4	5	6	7	8	9	10
Croatian Government Bonds	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4
Croatian Stocks	0.2	0.2	0.0	0.0	0.1	0.2	0.0	0.0	0.1	0.1
Cash	0.3	0.1	0.2	0.2	0.2	0.1	0.2	0.2	0.2	0.1
Hedge funds	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.1	0.1
Futures	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.1	0.1
EU Bonds	0.0	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.1
EU Stocks	0.0	0.1	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.1
Moments and efficiency measures										
Return	0.0017	0.0018	0.0023	0.0020	0.0020	0.0021	0.0027	0.0025	0.0022	0.0022
StdDev	0.0165	0.0205	0.0088	0.0125	0.0140	0.0186	0.0084	0.0077	0.0121	0.0149
Skewness	-1.818	-2.034	-1.142	-1.508	-2.057	-1.684	-0.998	-0.335	-1.570	-1.755
Kurtosis (Excess)	8.976	9.156	4.400	5.272	8.818	7.584	4.238	1.492	6.309	6.425
Sharpe Ratio	0.101	0.088	*0.265*	<u>0.164</u>	*<u>0.141</u>*	0.112	*0.322*	<u>0.321</u>	*<u>0.185</u>*	0.148
Sortino Ratio	0.131	0.110	*0.396*	<u>0.223</u>	*<u>0.180</u>*	0.145	*0.508*	<u>0.563</u>	*<u>0.251</u>*	0.193

Source: Authors' calculations

Portfolio 1 includes Croatian traditional investments – domestic bonds, stocks, and cash. Portfolios 2-10 combine foreign traditional and alternative investments to analyze their impact on returns and risks, testing Hypothesis 1. Portfolios 2-5 add EU bonds and stocks to domestic investments. Portfolio 2, with 10% of each foreign traditional type, is less efficient than Portfolio 1, compared using Sharpe and Sortino ratios. Portfolios 3 and 4, allocating 30% to EU bonds and stocks, outperform Portfolio 1, affirming their positive influence on returns and risks, with Portfolio 3 showing the highest ratios.

Portfolios 6-9, incorporating domestic traditional and alternative investments, also outperform Portfolio 1. Including alternative forms proves more beneficial than additional EU investments. Among simulated portfolios, Portfolios 7 and 8, with 20% hedge funds and 10% managed futures, are the most efficient. Portfolio 10, with diverse allocations, performs better than the initial one. Table 5 summarizes optimization results with additional US and global bonds and stocks.

Table 5: Optimization results (portfolios 11-19)

Type of investment/ # of portfolios	Shares in the portfolio								
	11	12	13	14	15	16	17	18	19
Croatian Government Bonds	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4
Croatian Stocks	0.2	0.0	0.0	0.1	0.2	0.0	0.0	0.1	0.1
Cash	0.1	0.2	0.2	0.2	0.1	0.2	0.2	0.2	0.1
US Bonds	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.1	0.1
US Stocks	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.1	0.1
Global Bonds	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.1
Global Stocks	0.1	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.1
Moments and efficiency measures									
Return	0.0021	0.0026	0.0026	0.0023	0.0025	0.0029	0.0032	0.0026	0.0028
StdDev	0.0207	0.0097	0.0125	0.0142	0.0202	0.0085	0.0121	0.0136	0.0171
Skewness	-1.951	-1.040	-1.366	-1.937	-2.045	-1.230	-1.283	-2.040	-1.906
Kurtosis (Excess)	9.077	4.953	5.265	8.736	9.257	6.075	4.939	8.856	7.894
Sharpe Ratio	0.103	*0.269*	<u>0.210</u>	<u>*0.160*</u>	0.122	*0.349*	<u>0.262</u>	<u>*0.189*</u>	0.167
Sortino Ratio	0.130	*0.414*	<u>0.299</u>	<u>*0.210*</u>	0.155	*0.547*	<u>0.382</u>	<u>*0.249*</u>	0.219

Source: Authors' calculations

Portfolios 11-19 examined the impact of adding more foreign traditional investments, including US and global financial market bonds and stocks. Although these additions slightly improved the efficiency of Portfolio 1, consisting of Croatian market investments, the improvement was minimal compared to including alternative forms. When US bonds and stocks were added, some portfolios performed better than those with alternative forms. Notably, Portfolio 8 (20% managed futures, 10% hedge funds) demonstrated the best performance with the highest Sortino ratio. Refer to Table 6 for a detailed summary of the optimization results.

Table 6: Optimization results (portfolios 20-27)

Type of investment/ # of portfolios	Shares in the portfolio							
	20	21	22	23	24	25	26	27
Croatian Government Bonds	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Croatian Stocks	0.2	0.0	0.0	0.1	0.2	0.1	0.1	0.1
Cash	0.1	0.2	0.2	0.2	0.1	0.1	0.2	0.1
EM Bonds	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0.1
EM Stocks	0.1	0.1	0.2	0.1	0.0	0.0	0.0	0.1
EU Corporate Bonds	0.0	0.0	0.0	0.0	0.2	0.3	0.2	0.1
Moments and efficiency measures								
Return	0.0011	0.0010	0.0016	0.0013	0.0020	0.0023	0.0022	0.0015
StdDev	0.0261	0.0245	0.0207	0.0202	0.0184	0.0127	0.0118	0.0208
Skewness	-2.916	-8.951	-3.486	-3.832	-1.921	-1.904	-1.872	-3.640
Kurtosis (Excess)	1.483	9.967	2.218	2.431	8.836	7.882	8.005	2.189
Sharpe Ratio	0.043	*0.039*	<u>0.075</u>	<u>*0.064*</u>	0.110	*0.184*	<u>*0.185*</u>	0.070
Sortino Ratio	0.051	*0.042*	<u>0.090</u>	<u>*0.075*</u>	0.140	*0.242*	<u>*0.245*</u>	0.082

Source: Authors' calculations

Incorporating additional investment forms (Portfolios 20-27) showed mixed results. Including emerging market securities didn't enhance Portfolio 1's efficiency, while introducing EU corporate bonds at 20% marginally improved Sharpe and Sortino ratios. More notable improvements were observed in Portfolios 25 and 26, albeit still falling short of Portfolios 6-9, which included alternative forms. Generally, alternative investments positively impacted portfolio returns and risk, measured by

Sharpe and Sortino ratios. Exceptions were seen in just two portfolios, emphasizing the overall efficacy of alternative investments.

Optimizing the portfolio with the described multi-criteria model begins with obtaining an efficient point, which is the starting point for the second optimization phase:

$$(E^*(R_P), \sigma_P^{2*}, S_P^*, K_P^*) = (0.0031, 0.006, -0.352, 0.481).$$

The efficient portfolio aims for maximum returns, minimum variance, maximum skewness, and minimum kurtosis. However, extreme values for skewness and kurtosis were not attainable due to defined constraints ensuring result comparability between Markowitz and multi-criteria optimization. The initial optimization phase, presented in Table 7, used a classical model, and the second phase employed a multi-criteria approach. The complexity of the analysis was managed using the R programming package, involving 210 covariance coefficients, 560 skewness coefficients, and 2.380 kurtosis coefficients.

Table 7: Values of moments of 4 portfolios obtained by optimization from the first stage (P1-P4)

Moments	Portfolio			
	1 (MAX return)	2 (MIN risk)	3 (MAX skewness)	4 (MIN kurtosis)
Return	0.0031	0.0029	0.0027	0.0026
StdDev	0.032	0.006	0.007	0.008
Skewness	-4.092	-0.646	-0.352	-0.365
Kurtosis (Excess)	3.130	1.979	0.705	0.481

Source: Authors' calculations

The portfolio structures obtained from the first optimization will be presented alongside those from the second phase.

In the second phase of the optimization, the goal was to minimize the distance from the efficient point $(E^*(R_P), \sigma_P^{2*}, S_P^*, K_P^*) = (0.0031, 0.006, -0.352, 0.481)$, with equal weights given to each moment ($\lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = 1$). The results, shown in Table 8, yielded the point $(E(R_P), \sigma_P^2, S_P, K_P) = (0.0031, 0.007, -1.229, 4.688)$. The distances of obtained moments from the efficient point were calculated, with the largest deviation observed in the kurtosis coefficient and the smallest in return and standard deviation, nearly reaching 0.

Table 8: Moment values of the optimal portfolio obtained by multi-criteria optimization (second phase)

Moments		Distance	
Return	0.0031	d_1	0.00002
StdDev	0.007	d_2	0.00049
Skewness	-1.229	d_3	0.87784
Kurtosis	4.688	d_4	4.20720

Source: Authors' calculations

Table 9 compares the structures of different portfolios obtained in the two phases of multi-criteria optimization.

Table 9: Structure investment portfolios obtained by multi-criteria optimization

Type of investment	Shares in the portfolio				
	First phase				*Second phase*
	P_1 MAX return	P_2 MIN risk	P_3 MAX skew.	P_4 MIN kurt.	
Croatian Government Bonds	0.00	0.20	0.18	0.18	0.18
Croatian Stocks	0.00	0.00	0.01	0.00	0.00
Cash	0.00	0.20	0.19	0.17	0.20
Hedge funds	0.20	0.08	0.06	0.00	0.18
Futures	0.00	0.09	0.20	0.18	0.02
EU Bonds	0.00	0.20	0.12	0.16	0.20
EU Stocks	0.00	0.00	0.00	0.03	0.00
US Bonds	0.20	0.20	0.18	0.13	0.20
US Stocks	0.20	0.00	0.01	0.00	0.00
Global Bonds	0.00	0.00	0.04	0.12	0.02
Global Stocks	0.20	0.00	0.00	0.02	0.00
EM Bonds	0.20	0.00	0.00	0.01	0.00
EM Stocks	0.00	0.00	0.00	0.00	0.00
EU Corporate Bonds	0.00	0.03	0.01	0.00	0.00
Total	1.00	1.00	1.00	1.00	1.00

Source: Authors' calculations

In the final step of this analysis, the results of two types of optimizations were compared. Equal constraints were applied to investment allocations in both Markowitz and multi-criteria optimization for a fair comparison. The latter proved to be the most efficient, as confirmed by the Omega ratio. The normality test indicated non-normality in several portfolios, justifying the use of the Omega ratio. Only the MIN kurtosis portfolio showed potential normality according to the Jarque-Bera test. Table 10 contains the results.

Table 10: Results of Markowitz (MV5) and multi-criteria (MVSK6) optimization

Measure	Multi-criteria optimization			Markowitz optimization			
	MVSK (w_o=EW)	MVSK (w_o=DR)	MVSK (w_o=ERC)	MAX return	MIN risk	MAX skew.	MIN kurt.
Expected return	0.0031	0.0029	0.0029	0.0031	0.0029	0.0027	0.0026
Stand. deviation	0.007	0.006	0.006	0.032	0.006	0.007	0.008
Skewness	-1.229	-0.646	-0.646	-4.092	-0.646	-0.352	-0.365
Kurtosis	4.688	1.979	1.979	3.130	1.979	0.705	0.481
Omega[7]	3.536	3.394	3.394	1.390	3.394	2.738	2.373
Jarque-Bera	210.18	41.88	41.89	575.80	41.89	7.44	5.73
p-value	0.000	0.000	0.000	0.000	0.000	0.024	0.057

Source: Authors' calculations

Given that the multi-criteria model simultaneously optimizes the first 4 central moments of the distribution, their efficiency is still at a certain level higher than the *MIN risk* portfolios obtained by Markowitz optimization.

4.3. Estimating the impact of interest rate changes within the VAR model

The results of the VAR model aim to enhance understanding of the intensity of the impact of interest rate changes on the returns of selected traditional and alternative investment forms. This study seeks to emphasize the diminished influence of interest rate fluctuations on alternative investments, reducing the risk of abrupt changes. The analysis covers domestic stocks and bonds as conventional investments, and hedge funds and managed futures as alternative options.

[5] Mean-Variance (MV).

[6] Mean-Variance-Skewness-Kurtosis (MVSK)

[7] Loss threshold set to 0 according to the initial settings of the Omega function in R studio.

The initial step involves conducting stationarity tests. Results indicate that, with a significance level of 5%, all observed variables are stationary, as evidenced by the test statistics and p-values, leading to the rejection of the null hypothesis of non-stationarity, except for the EURIBOR variable. In the case of EURIBOR, the null hypothesis of non-stationarity can be rejected at a 10% significance level, with a lag of 1 in the ADF test yielding a p-value of 0.01. Similarly, the Phillips Perron test supports the rejection of the null hypothesis for the EURIBOR variable, confirming its stationarity. Following the determination of the integration order of the analyzed time series, further VAR analysis can proceed.

Table 11 shows the results of the VAR model estimation, but only for the interest rate variable (i.e., EURIBOR).

Table 11: Results of a VAR(1) model – EURIBOR variable

Variable	Estimate	Std. error	t statistic	Pr (>| t |)
EURIBOR	0.4137	0.0688	6.01	0.000
CROBIStr	-1.7367	1.7301	-1.00	0.32
CROBEXtr	0.1533	0.39	0.39	0.69
Hedge Fund	-0.7934	1.2708	-0.62	0.53
MFutures	0.6054	1.0315	0.59	0.56
const	-0.0339	0.0205	-1.65	0.10

Source: Authors' calculations

Following the model estimation, it is necessary to conduct an innovation analysis, starting with the implementation of the Granger causality test for each individual variable in the model concerning the other variables. The null hypothesis of the Granger causality test assumes no causality in the Granger sense. Consequently, the test results indicate that the EURIBOR variable does not cause other variables in the Granger sense, except for the Hedge funds variable, where the null hypothesis is rejected.

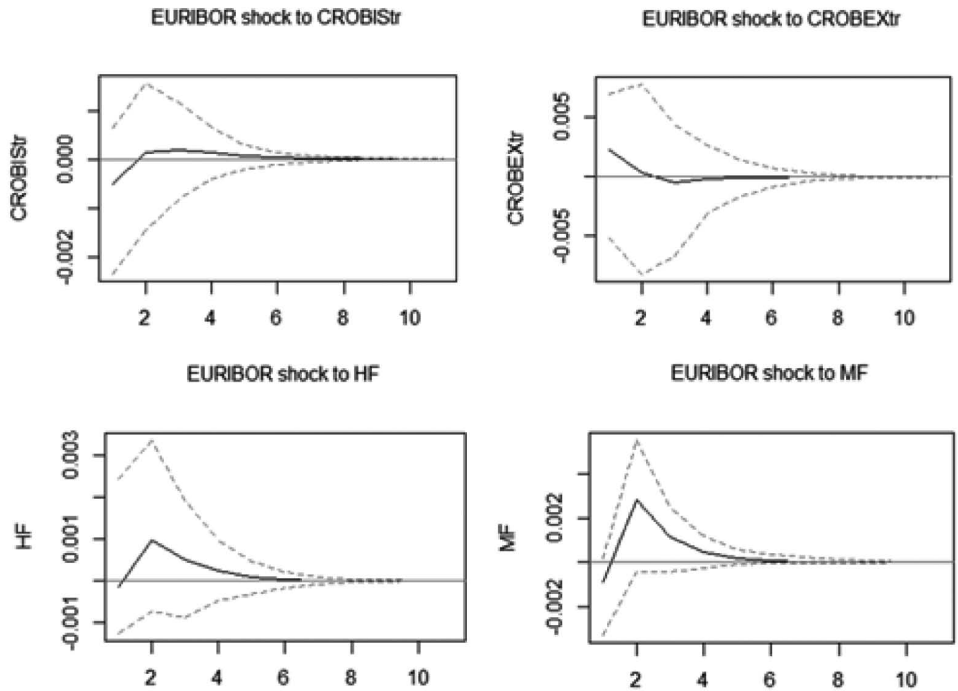
Table 12: Results of the Granger causality test for the VAR(1) model

Variable	Test stat (F-test)	p-value	Interpretation
EURIBOR	1.24	0.29	cannot reject H_0
CROBIStr	1.36	0.26	cannot reject H_0
CROBEXtr	0.31	0.87	cannot reject H_0
Hedge Fund	3.98	0.00	rejecting H_0
MFutures	1.48	0.21	cannot reject H_0

Source: Authors' calculations

Picture 1 displays the innovation analysis conducted over a period of 10 months.

Picture 1: Impulse response function for the VAR(1) model and the shock in the EURIBOR variable



Source: Constructed by authors

A one-standard deviation interest rate change doesn't significantly impact other variables within the 95% confidence interval.

Table 13: Coefficients of the impulse response function (EURIBOR impulse variable)

N	CROBIStr	CROBEXtr	Hedge Fund	MFutures
1	-0.00050632	0.00231476	-0.00014509	-0.00089154
2	0.00014389	0.00029372	0.00097661	0.00281624
3	0.00018526	-0.00052517	0.00051283	0.00112809
4	0.00013433	-0.00012119	0.00023965	0.00046064
5	0.00007289	-0.00004496	0.00009637	0.00017668
6	0.00003496	-0.00002364	0.00003613	0.00006772
7	0.00001562	-0.00001387	0.00001296	0.00002594
8	0.00000668	-0.00000758	0.00000453	0.00000996
9	0.00000278	-0.00000382	0.00000156	0.00000383
10	0.00000113	-0.00000180	0.00000053	0.00000147
11	0.00000045	-0.00000081	0.00000018	0.00000057

Source: Authors' calculations

The impulse response coefficients show a drop in yields on domestic bonds, hedge funds, and managed futures in the first month, stabilizing thereafter.

Table 14: Variance decomposition of VAR (1) model – EURIBOR variable

N	EURIBOR	CROBIStr	CROBEXtr	Hedge fund	MFutures
1	1.000000	0.000000	0.000000	0.000000	0.000000
2	0.991050	0.005936	0.000000	0.001370	0.001640
3	0.987170	0.008987	0.000001	0.001979	0.001859
4	0.986070	0.009852	0.000002	0.002171	0.001902
5	0.985830	0.010045	0.000002	0.002216	0.001909

Source: Authors' calculations

Variance decomposition reveals that EURIBOR, representing interest rate changes, explains only a small part of the variations in selected investment yields. This weak explanatory power could be due to the choice of the interest rate variable (3M EURIBOR) and the insignificance of certain variables in the VAR model.

In conclusion, it's important to note that several tests, including autocorrelation of residuals and heteroskedasticity, were conducted in this analysis. Due to the extensive nature of the study, detailed results were not included in this summary but are available upon request.

5. Findings and discussion

The first hypothesis suggested that integrating alternative forms of investment into portfolios would have a stronger positive impact on both returns and risks compared to adding more traditional investment forms. This hypothesis was confirmed by testing different combinations of domestic and foreign traditional as well as alternative investments. The study provided valuable insights into the empirical effects of including alternative investments in portfolios. Simulated portfolios, retaining shares of domestic traditional forms, accurately reflected real investment portfolios, offering practical applications for institutional investors based on the tested hypothesis.

When it comes to the empirical limitations of this research, it is necessary to mention the exemption of the asset liability management principle in performing optimization. The formation of insurers' investment portfolios is greatly influenced by the structure of liabilities. The impact of this approach was mitigated by imposing constraints on the wights of domestic investments, where a significant share is occupied by government bonds, which approximates the real structure of the investment portfolio of insurance companies.

Results of testing the first hypothesis conform with previous research findings of Kat (2005), Otruba et al. (2006), Hoevenaars et al. (2008), Jaggi et al. (2011), Abrams et al. (2012, 2014) and Štimac (2012) since adding hedge funds and managed futures to a portfolio of traditional investments significantly improves the portfolio efficiency. Main difference here is that in this research domestic (Croatian) bonds and stock are used, but also other foreign traditional investment classes while the observed period is very versatile and long.

This hypothesis also included testing if using a multi-criteria optimization model, incorporating multiple distribution moments, would result in a more efficient investment portfolio than one optimized using the traditional Markowitz model. Results from the testing have confirmed it, indicating that the multi-criteria model consistently outperformed the Markowitz optimization model, considering various constraints. This flexibility allowed investors to adjust preferences according to their investment goals, offering room for further analysis by optimizing different weights for specific central moments of the distribution.

With regards to portfolio composition using multi-criteria optimization, results are in line with Davies et al. (2009) since performing optimization without constraints on minimum allocation, hedge funds squeeze out domestic and foreign equities due to high co-asymmetry. Comparing the results of testing the hypothesis with findings of Bergh and Rensburg (2008), a portfolio obtained with multicriteria optimization outperformed the ones obtained with Markowitz optimization when compared using Omega measure. According to the findings of Gautefall and Chen (2017), this research demonstrates that portfolios optimized for higher moments outperform those optimized using the traditional Markowitz framework.

The purpose of testing the second hypothesis was to gain a more in-depth understanding of how changes in interest rates affect the returns of specific traditional and alternative investments. However, the results from the VAR analysis did not show a significant correlation or influence of interest rate changes on stock and bond returns, contrary to economic expectations. Additionally, the impact of interest rates on alternative investments was not assumed beforehand due to the limited research available on the effects of interest rates on hedge funds and managed futures.

While this hypothesis was not entirely confirmed based on the test results, it cannot be completely dismissed considering previous research findings. Despite this, the hypothesis testing provided valuable insights into the relationship between the variables studied. To expand the scope of hypothesis testing, it is feasible to choose another variable representing interest rate movements, such as returns on money market instruments, long-term loan rates, or the ECB refinancing rate. However, due to the stability of the variables in the model, the applicability of cointegration methods, as demonstrated in Jakšić's (2008) work, for further testing the impact of interest rates on specific types of investments remains uncertain.

Economic theory and logic assume a certain direction and intensity of the connection between macroeconomic variables and financial markets, or in this case changes in interest rates on the yields of stocks and bonds. Given the more intense interrelationship between interest rates and traditional forms of investment, changes in interest rates are expected to have a weaker impact on changes in the yield of alternative forms such as hedge funds and futures. Unfortunately, this perceived relationship couldn't be confirmed by testing the second hypothesis which was the case with other previous research.

6. Conclusion

By incorporating non-traditional investments into institutional portfolios, a balanced strategy that considers both returns and risks becomes achievable. The empirical findings from the research support the initial hypothesis. Examining the impact of introducing non-traditional investments to a portfolio of Croatian assets, the study demonstrated that these alternatives had a positive influence on portfolio efficiency, as indicated by the Sharpe and Sortino ratios. Furthermore, when comparing a multi-criteria optimization model with the conventional Markowitz model, the study revealed the superior efficiency of the multi-criteria approach, providing valuable insights for investors. The second hypothesis, which explored the effect of changes in interest rates on various investments, produced nuanced results.

A significant contribution of this study is the development of a sophisticated multicriteria optimization model, enabling stakeholders to strike an optimal balance between traditional and alternative investments. Unlike previous studies, this research accounts for the non-normal distribution of variables, providing a more accurate representation of real-world investment scenarios. Addressing a gap in the literature, the study optimizes portfolios by incorporating reference alternative investments like hedge funds and managed futures alongside traditional assets, enriching the understanding of diversification and risk management within Croatia's financial landscape. The study offers valuable insights and practical applications, serving as a crucial tool for researchers and practitioners in the finance industry.

However, like most scientific research, it has limitations. It relies on historical data, which could lead to errors in estimating key return distribution parameters. To counter this, a significant time series of 180 monthly observations from 2006 to 2020 was employed. Differences in data characteristics among financial indices were addressed, and limitations related to insurance companies' obligations were abstracted, with a focus on life insurance companies. The optimization models, particularly the Markowitz model, have constraints due to their periodic nature and reliance on historical data. The VAR methodology used for testing also faces limitations related to autocorrelation and heteroskedasticity of residuals.

By overcoming limitations such as historical data use, this study forms a robust foundation for future research in insurance companies' investments and wider institutional and professional investor domains. Suggestions for future research include employing advanced methods to assess investment returns, incorporating various alternative investment forms, testing results over different time periods, and analyzing investor reactions post Croatia's entry into the eurozone.

Research shows that including alternative investments significantly enhances portfolio efficiency, as measured by Sharpe and Sortino ratios, in most tested combinations. This diversification benefit underscores the importance of incorporating these investments. Practical results highlight the advantages of a multi-criteria model coded in R, made accessible for investors. For those heavily invested in bonds and stocks, adding hedge funds and managed futures of specific maturity, or reducing bond and stock allocations can mitigate interest rate risks. These findings confirm that combining alternative and traditional investments creates a more efficient portfolio compared to one with only traditional investments.

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Optimizacija investicijskih portfelja osiguratelja uključivanjem alternativnih oblika ulaganja

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Sažetak

Povijesno niske kamatne stope predstavljaju značajan izazov za društva za osiguranje, posebice ona specijalizirana za životna osiguranja. Ovaj rad istražuje potencijalno rješenje analizirajući učinak uključivanja alternativnih ulaganja niske korelacije u tradicionalne investicijske portfelje. U tu svrhu, koriste se dvije metode. Prva metoda, optimizacija pomoću Markowitzovog modela i višekriterijski model optimizacije koristi se za testiranje prednosti uključivanja alternativnih oblika ulaganja. Kao drugo, rad procjenjuje učinke fluktuacija kamatnih stopa na tradicionalna i alternativna ulaganja putem modela vektorske autoregresije (VAR). Rezultati iz oba optimizacijska modela tijekom analiziranog razdoblja pokazuju da integracija alternativnih ulaganja pozitivno utječe na povrate portfelja, upravljanje rizikom i ukupnu učinkovitost. Osim toga, rad istražuje utjecaj promjena kamatnih stopa na domaće dionice, obveznice, hedge fondove i ročnice. Unatoč teoretskim očekivanjima značajnog utjecaja, nije moguće u potpunosti potvrditi da promjena kamatnih stopa jače utječe na promjenu prinosa obveznica i dionica nego što utječe na prinose hedge fondova i ročnica. Sveukupno, istraživanje naglašava značaj diversifikacije investicijskih portfelja s alternativnom imovinom niske korelacije kao odgovor na izazov niskih kamatnih stopa, pružajući vrijedne uvide društvima za osiguranje za snalaženje na financijskim tržištima.

Ključne riječi: *društva za osiguranje, alternativna ulaganja, kamatne stope, investicijski portfelj, optimizacija portfelja*

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